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ORIGINAL RESEARCH

Effect of Social Determinants of Health and Geography on Uveal Melanoma

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Purpose: This study aims to examine the geographic distribution of ocular oncologists in the United States and evaluates how social determinants of health (SDOH) and environmental factors influence access to ocular oncologists nationally and uveal melanoma (UM) outcomes locally at the University of Illinois (UI) Hospital.

Patients and Methods: A national analysis mapped ocular oncologist locations using ArcGIS Pro, assessing accessibility via drive-time radii (15–60 minutes) and census tract population density. SDOH variables (income, education, and insurance) were extracted from US Census data. A retrospective chart review of 167 UM patients at UI Hospital (2010–2023) analyzed tumor characteristics, referral patterns, and SDOH/environmental factors linked to zip codes. Statistical analyses included t-tests, logistic regression, and False Discovery Rate correction.

Results: Nationally, 33.5% of the population, including 45.9% of rural residents, live beyond 60 minutes of an ocular oncologist. Areas outside of an accessible distance of an ocular oncologist were more likely to have low-income, less-educated, and uninsured populations ($p < 0.001$). At UI Hospital, patients outside a 60-minute radius required significantly more referrals ($p = 0.046$) but showed no differences in tumor stage at presentation. Trends suggested larger tumor thickness in areas with fewer naturalized citizens and more households under the Asset Limited, Income Constrained, Employed threshold. ($q = 0.068$ and $q = 0.093$, respectively). Environmental factors showed no significant associations, including Lifetime Inhalation Cancer Risk, Water Polluting Sites Environmental Justice Index, and Optometrists Per Capita.

Conclusion: There may be geographic and socioeconomic barriers that limit access to UM care, particularly in rural and underserved communities. While proximity did not affect tumor presentation at UI Hospital, referral delays and socioeconomic trends highlight systemic inequities. Multicenter studies are needed to further explore these disparities and improve equitable UM care delivery.

Keywords: uveal melanoma, geography, social determinants, barriers to care

Introduction

Uveal melanoma (UM) is the most common intraocular malignancy in adults, with an estimated disease incidence of approximately 5 cases per million per year in the United States (US).[1] Despite the low incidence, investigation of UM is of particular importance given that it has a poor prognosis, with a mortality rate of approximately 25% at 15 years.[2] Although the impact of genetics for UM is well characterized, research regarding the impact of social determinants of health (SDOH) and geography on the management and presentation of UM is limited.

SDOH are defined as “the conditions in the environments where people are born, live, learn, work, play, worship, and age that affect a wide range of health, functioning, and quality-of-life outcomes and risks.” SDOHs have previously been found to be associated with the presentation of other types of cancers. For instance, patients of a lower socioeconomic status have previously been found to present with an advanced breast cancer stage and suffer a higher mortality.[3,4] Moreover, lower income, lower education, and residence in disadvantaged neighborhoods have previously been found to

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be associated with higher incidence, later stage at presentation, and poorer outcomes in other forms of cancer, such as lung, breast, prostate, and colorectal cancer.[4,5] In addition, uveal melanoma patients with lower income and lack of insurance have been found to present with advanced stage melanomas.[6] However, other social determinants of health, such as proximity to optometrists or low food access, and their impact on uveal melanoma presentation is limited. Given the well-established link between other forms of cancer and SDOHs, we aim to investigate the association between SDOHs and uveal melanoma at presentation.

An additional factor that has been sparsely investigated with regard to the presentation of UM are environmental risk factors. Few environmental risk factors have been identified to be associated with the pathogenesis of UM, such as ultraviolet B spectrum radiation, sun exposure timing, sun exposure frequency, and welding.[7,8] Additionally, states with greater access to fluoridated water appeared to have lower incidence rates of uveal melanoma.[9] Further research into environmental risk factors is warranted as these environmental risk factors have been found or theorized to associate with the incidence rates and tumorigenesis of other types of cancer. For example, Cheng et al and Su Liu et al discovered a positive association between air contaminants and the incidence of lung cancer.[10,11] Furthermore, contaminants or pollutants in drinking water have been found to be associated with an increased incidence of many types of cancer.[12] In addition to these previously found associations, environmental contaminants, such as chemical waste, air pollutants, or water pollutants, can cause chronic inflammation. Chronic inflammation is known to promote carcinogenesis via inducing DNA damage and increasing cell turnover.[13,14]

Geographic location not only determines an individual's direct access to care but also may influence other key sociodemographic factors, such as income, environmental exposure, and healthcare infrastructure.[15] A systematic analysis of 171 countries previously found that regions with lower resource levels, often rural areas, face higher cancer mortality and lower survival.[16] Moreover, in the United States, previous literature has shown that patients in rural areas often have a more severe cancer stage at diagnosis for several types of cancer, such as breast, colorectal, lung, and prostate cancer.[17–19] Despite the well-established link between cancer and geography for other types of cancer, there is limited understanding of how geography plays a role in accessing appropriate UM care. A national analysis done by Lieu et al highlights the fact that there are lower densities of ocular oncologists in rural regions.[20] However, to our knowledge, there is no prior literature discussing how geography may affect patient-specific outcomes in uveal melanoma.

Thus, the present study aims to identify areas in the US with high unmet need for ocular oncologists based on the geographic distribution of ocular oncologists and population density. We also aim to report on other potential disparities in SDOHs, such as income and education, that may be associated with a lack of access to ocular oncology care. Furthermore, the present study also aims to report on SDOHs and geographic factors that may affect the presentation and management of UM patients at the University of Illinois (UI) Hospital.

Materials and Methods

The 2024 US Census Bureau data was used to extract SDOH and other relevant geographical data for each census in the US. A list of ophthalmologists who provide UM care was made by calling the offices to confirm the presence of an ocular oncologist as listed by ophthalmological societies (American Academy of Ophthalmology, American Association of Ophthalmic Oncologists and Pathologists, International Society of Ocular Oncologists, Melanoma Research Foundation, Eye Care Foundation, and A Cure in Sight Ocular Melanoma). Their locations were confirmed, along with those of any relevant satellite offices, and then loaded into ArcGIS Pro (Version 3.3.0, ESRI, United States). Census tracts outside the contiguous US were excluded from analysis.

Using the service area analysis tool in ArcGIS, areas within 15, 30, 45, and 60 minutes of drive time were determined based on traffic during a regular workday during business hours. A threshold of 60 minutes was designated as accessible distance in accordance with the Health Resource and Services Administrations score guidelines for healthcare shortages.[21] In other words, individuals who lived within 60 minutes of an ocular oncologist were considered to be in an area with accessibility, while those who lived further than 60 minutes away were considered to be in an area outside of accessibility. In both previous global and regional literature, a threshold of 60 minutes was used to determine accessibility among other domains of healthcare.[22–24] For example, Baldomero et al found that patients with drive times of 61 minutes or higher were less likely to receive guideline recommended preventative primary care when compared to patients who lived within a 60-

minute radius of a health care center.[22] Population densities for individuals older than 18 was calculated for each census tract based on US census data and placed into density quartiles. A map of population density quartile was generated for contiguous US census tracts. This was then overlaid with the drive time map to determine census tracts that had both inaccessibility to an ocular oncologist and high population density.

A variety of SDOH variables were extracted from the 2024 US Census Bureau data for each associated census tract: age, sex, race, ethnicity, rural or urban designation, highest education level, mean household income, number of households with children in poverty, number of households with children under 5 in poverty, number of households with internet access, number of households with 0, 1, or 2 vehicles. Chi-squared tests and two-sample t-tests were used to compare categorical and continuous socioeconomic variables, respectively, between census tracts within and outside of accessible distance. All analyses were performed using R (R Core Team (2023)386).

A descriptive sub-analysis was also conducted to determine if any regions of the contiguous US experienced better or worse access to care. The contiguous US was divided into five regions based on the US Census Bureau's predetermined regions: Northeast, Midwest, South, Mountain, and Pacific regions.[25] The percent within accessible distance in each region was determined.

For patient specific data collected from UI Hospital, the Institutional Review Board approval (STUDY2023-0866) for this study was obtained from the University of Illinois Chicago. Patients who were diagnosed with UM based on relevant International Classification of Diseases 10 codes from 2010 to 2023 at the University of Illinois Hospital were included in the retrospective chart review. All recorded data were stored in a HIPAA compliant RedCAP file (Vanderbilt University, Nashville, TN, USA). A brief overview of our methodology for this patient-level analysis may be seen in Figure 1.

In this retrospective chart review, the following demographic variables were recorded: age at diagnosis, race, sex, date of birth, full address, past medical history, symptom duration prior to seeing ocular oncologist, and number of referrals until seeing a UI Health ocular oncologist. Additionally, the following tumor presentation characteristics were recorded: largest basal diameter, tumor thickness, extraocular extension, treatment, and metastasis. Tumor volume was also calculated using previously described methods.[26] Of the patients who were diagnosed with UM from 2010 to 2023, patients who did not have UM upon chart review or were missing one or more of the above variables were excluded from this study. Working with the UI Health Cancer Center, approximately 180 SDOH variables were obtained using each patient's zip code. Of these numerous SDOH variables, variables of particular interest include households below Asset Limited, Income Constrained, Employed (ALICE) index, naturalized US citizens, area deprivation indices, rent burden, optometrists per capita, primary care physicians per capita, and specialist physicians per capita. Furthermore, over 30 continuous different environmental variables were also obtained using each patient's zip code. Of these numerous environmental variables, variables of particular interest include water pollution environmental justice index, chemical accidents environmental justice index, particulate matter concentration, and respiratory hazard index.[10–12] Multivariate linear regression models were used to study the association between each of these SDOH and environmental variables and the continuous tumor presentation characteristics, such as tumor thickness, basal diameter and tumor volume. Due to the skewed distribution, logarithm transformations were applied for tumor thickness and tumor volume. For categorical tumor presentation characteristics, their associations with each SDOH and environmental factors were evaluated by multivariate logistic regression models. All models were adjusted for confounders, such as age and gender. False Discovery Rate (FDR) correction was used to adjust for multiple testing. A threshold of $q < 0.05$ is considered to be statistically significant after FDR correction.

Patient's addresses were then geocoded into ArcGIS Pro (Version 3.3.0, ESRI, United States). Additionally, the address of UI Hospital was also geocoded into ArcGIS Pro. Using the service area analysis tool in ArcGIS, areas within 15, 30, 45, and 60 minutes of drive time were determined based on traffic during a regular workday during business hours. Similar to that of the national analysis, a threshold of 60 minutes was used to determine accessibility. Patient-level demographics and tumor characteristics at presentation were then compared between patients that lived within 60 minutes and outside of 60 minutes of UI Hospital. Continuous variables were expressed as median with interquartile range (IQR) and compared by the Wilcoxon rank-sum test. Categorical variables were presented as count (%) and their relationships with accessible distance were evaluated using Chi-squared test or Fisher's exact test for sparse counts. All

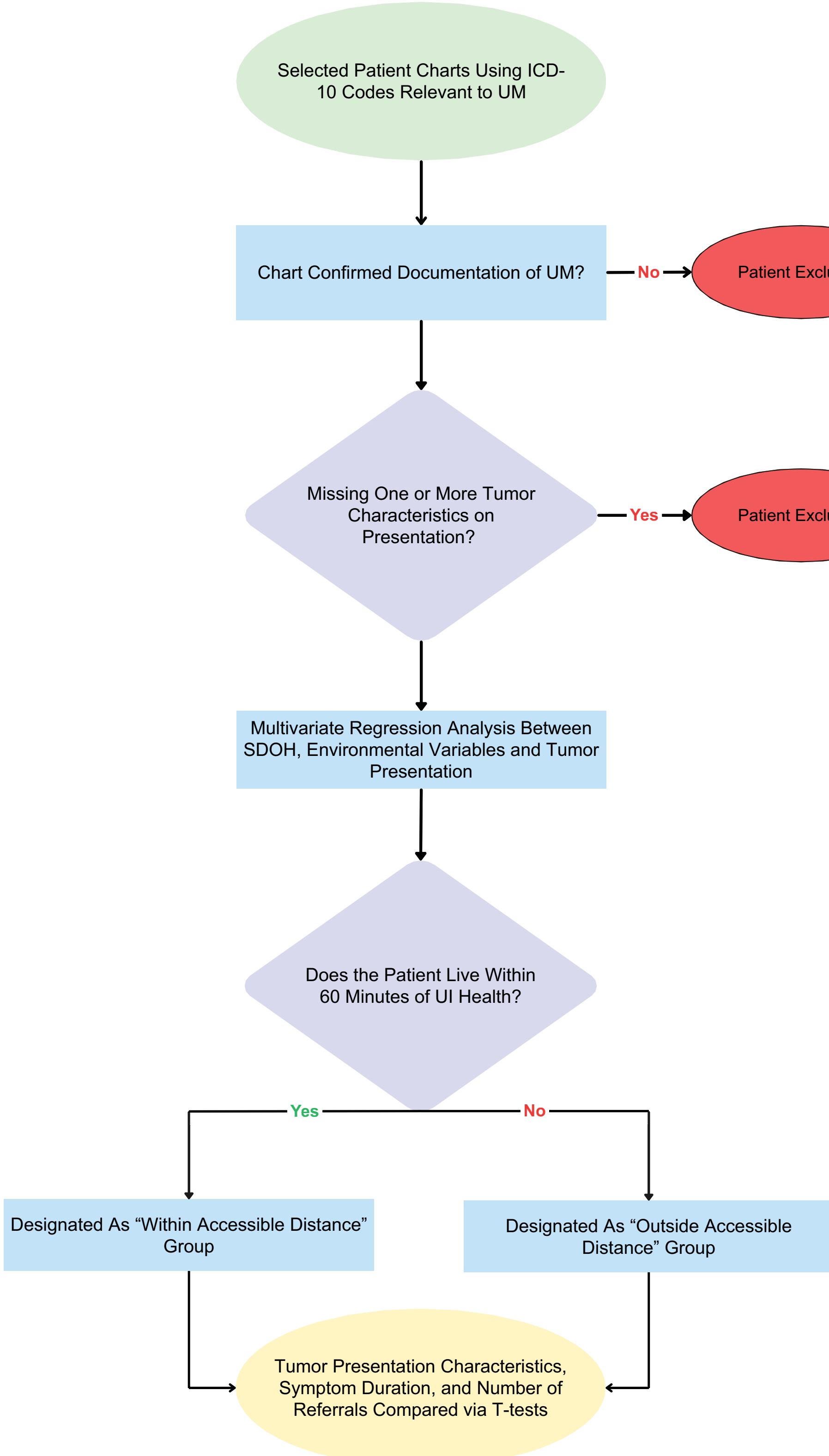

Figure 1 Brief Overview of the Patient Level Analysis Methodology.

statistical analyses were conducted using software R (version 4.4.3). All statistical tests were two-sided, controlling for type I error probability of 0.05.

Results

National Ocular Oncologist Availability Analysis

A total of 127 ocular oncologists with 238 unique office addresses were identified. Figure 2 displays a map of the contiguous US with 15-, 30-, 60, and 120-minute drive time radii around each office address. A total of 219,313,260 (66.5%) of individuals were found to live within an accessible distance of an ocular oncologist, while 110,496,266 (33.5%) of individuals were found to live outside of an accessible distance of an ocular oncologist (Table 1). Furthermore, 45.9% of the rural population in the US were found to be outside of an accessible distance of an ocular oncologist (Table 1). Table 2 displays the proportions of each region within and outside of an accessible distance of an ocular oncologist. For reference, Figure 3 displays a map of population quartiles of the contiguous US.

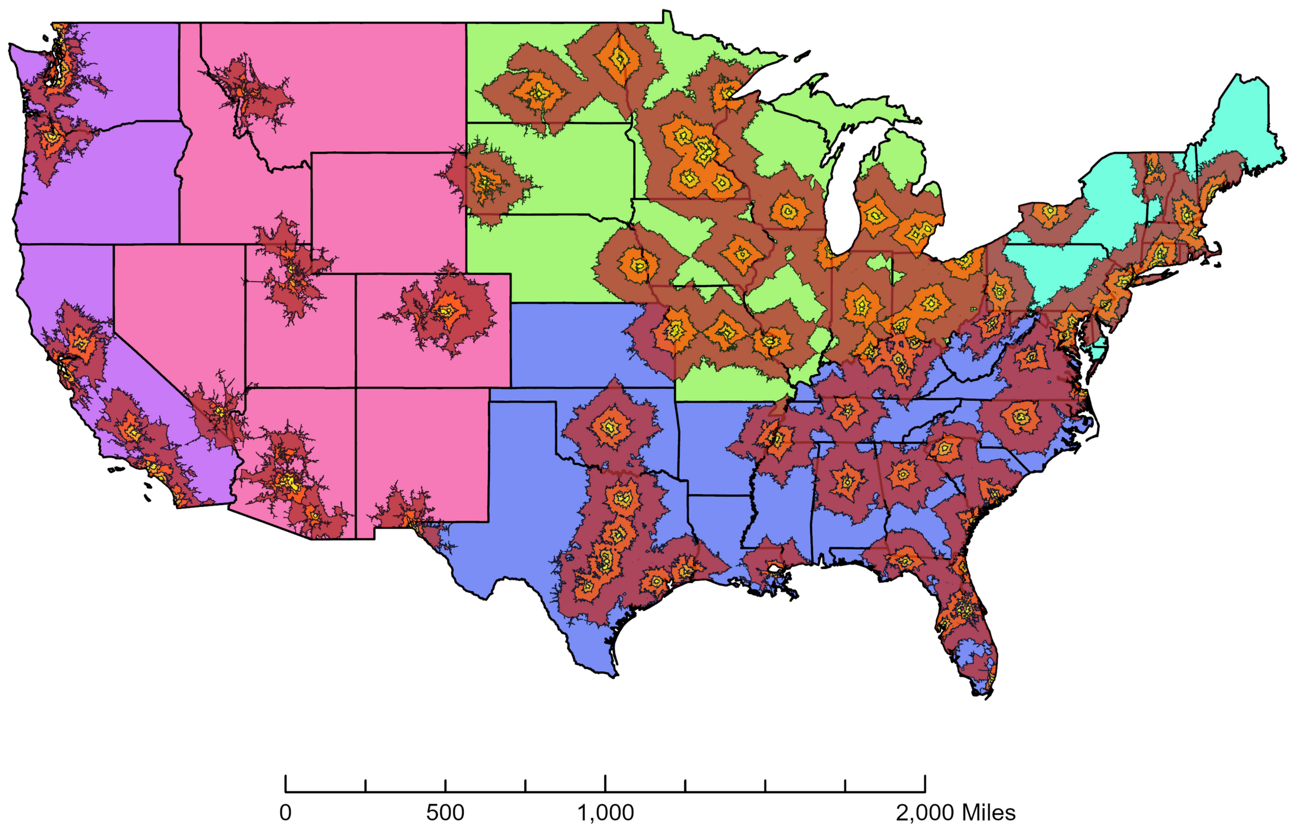

Figure 2 Map of the contiguous United States with 15- (yellow), 30- (light Orange), 45- (dark orange), and 60-minute (red) drive time radii around every identified ocular oncologist that provides UM care. The following state regions, as designated by the United States Census Bureau, are represented: Midwest (green), Mountain (pink), Northeast (turquoise), Pacific (purple), South (blue).

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Table 1 Overall Characteristics of Nationwide Population Included for Analysis

	Total	Within Accessible Distance[1]	Proportion of Total within Accessible Distance	Outside Accessible Distance[1]	Proportion of Total Outside Accessible Distance
Overall					
Population	329,809,526	219,313,260	66.5%	110,496,266	33.5%
Urban Population[2]	262,708,238	177,061,561	67.4%	85,646,677	32.6%
Rural Population[2]	65,357,197	35,374,647	54.1%	29,982,550	45.9%
Households	126,580,229	83,818,211	66.2%	42,762,018	33.8%

Notes: [1]Within accessible distance defined as Driving Time < 60 minutes from nearest ocular oncologist, outside accessible distance defined as driving time > 60 minutes from nearest ocular oncologist. [2]Rural and Urban population was determined from 2024 United States Census Bureau Data.

Table 2 Population of Individuals by Region

	Total	Within Accessible Distance[1]	Proportion of Region within Accessible Distance	Outside Accessible Distance[1]	Proportion of Region Outside Accessible Distance
By Region					
Midwest	57,107,907	34,360,228	60.2%	22,747,679	39.8%
Mountain	25,244,033	15,506,013	61.4%	9,738,020	38.6%
Northeast	60,324,364	43,081,054	71.4%	17,243,310	28.6%
Pacific	51,222,483	39,125,691	76.4%	12,096,792	23.6%
South	136,225,947	87,279,360	64.1%	48,946,587	35.9%

Figure 4 displays census tracts categorized by need for an ocular oncologist, which was determined based on the drive time radii seen in Figure 2 and the population quartiles seen in Figure 3. The areas highlighted in the darkest shade of red indicate areas of significant need, as these areas have a high population density and are outside of an accessible distance of an ocular oncologist. Additionally, individuals living in census tracts outside of an accessible distance were found to have a significantly lower median income than those living within an accessible distance ($69,916 vs $90.533; $p < 0.0001$) and lower rates of being insured (91.2% vs 91.7%; $p < 0.0001$) than those who were living within an accessible distance (Table 3). Furthermore, there was a significantly higher proportion of families in poverty outside of an accessible distance than within (9.9% vs 8.1%; $p < 0.0001$) (Table 3). Lastly, there was a significantly lower proportion of individuals that graduated from high school (87.9% vs 88.5%; $p < 0.0001$) or with a bachelor's degree outside of an accessible distance of an ocular oncologist than within (26.6% vs 37.2%; $p < 0.0001$) (Table 3).

Patient Level Geographic and Sociodemographic Analysis

After our inclusion and exclusion criteria, a total of 167 patients were included for our patient-specific geographic and sociodemographic analysis and had all necessary data for analyses. Of our patient sample, the median age was 64 years (Table 4). Furthermore, the median tumor diameter, thickness, and volume at presentation was 11.5 mm, 5.3 mm, and 291 mm^3, respectively (Table 4). Furthermore, Figure 5 displays approximate locations of our patient sample in relation to 15-, 30-, 60, and 120-minute drive time radii around UI Hospital. There were no significant differences in tumor characteristics between patients that live within an accessible distance of and patients that live outside an accessible distance of UI Hospital (Table 4). Furthermore, Table 5 displays the correlation between tumor thickness and a selection of sociodemographic and environmental variables with notable trends. As seen in this table, the following trends were identified: patients from areas with fewer naturalized US citizens, patients from areas with higher prostate cancer

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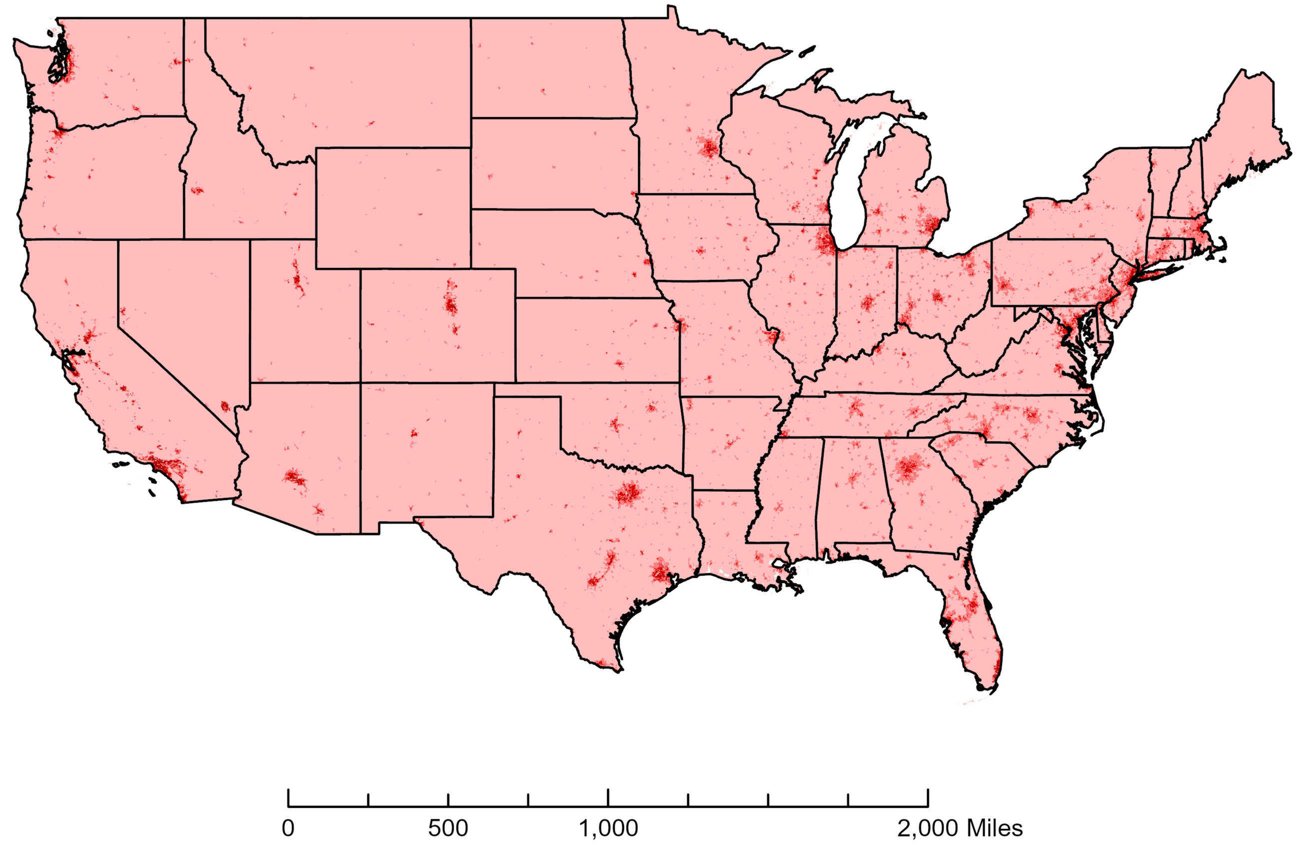

Figure 3 Population density quartile map of the contiguous United States. Darker shades of red indicate areas with a higher population density quartile.

diagnosis rates, and areas with higher blood pressures tended to have larger tumor thicknesses ($q = 0.068$, $q = 0.09$, and $q = 0.09$, respectively). Other sociodemographic and environmental variables not listed in this table were not found to be significant (see Supplemental Table 1). Other tumor characteristics, such as extraocular extension, basal diameter, and tumor volume, did not have any significant relationships or notable trends.

Referral Pattern Analysis of Patients Within and Outside of an Accessible Distance of UI Hospital

Patients living outside a 60-minute radius of UI Health had a mean number of 1.75 referrals to other providers for a higher level of care before seeing an ocular oncologist at UI Health, which was significantly higher than patients living within 60 minutes of UI Health who had a mean number of 1.39 referrals ($p = 0.046$, Table 6). Symptom duration prior to diagnosis was not significantly different between patients outside of or within a 60-minute radius of UI Health.

Discussion

The present study aims to provide a nuanced geographic service analysis of ocular oncologists in the United States, along with certain SDOHs which may further complicate the ocular oncologist geographic service areas. In their investigation of the geographic distributions of ocular oncologists across states, Lieu et al concluded that states with higher rural populations and lower urbanization had a higher relative demand for ocular oncologist care. Similarly, based on census

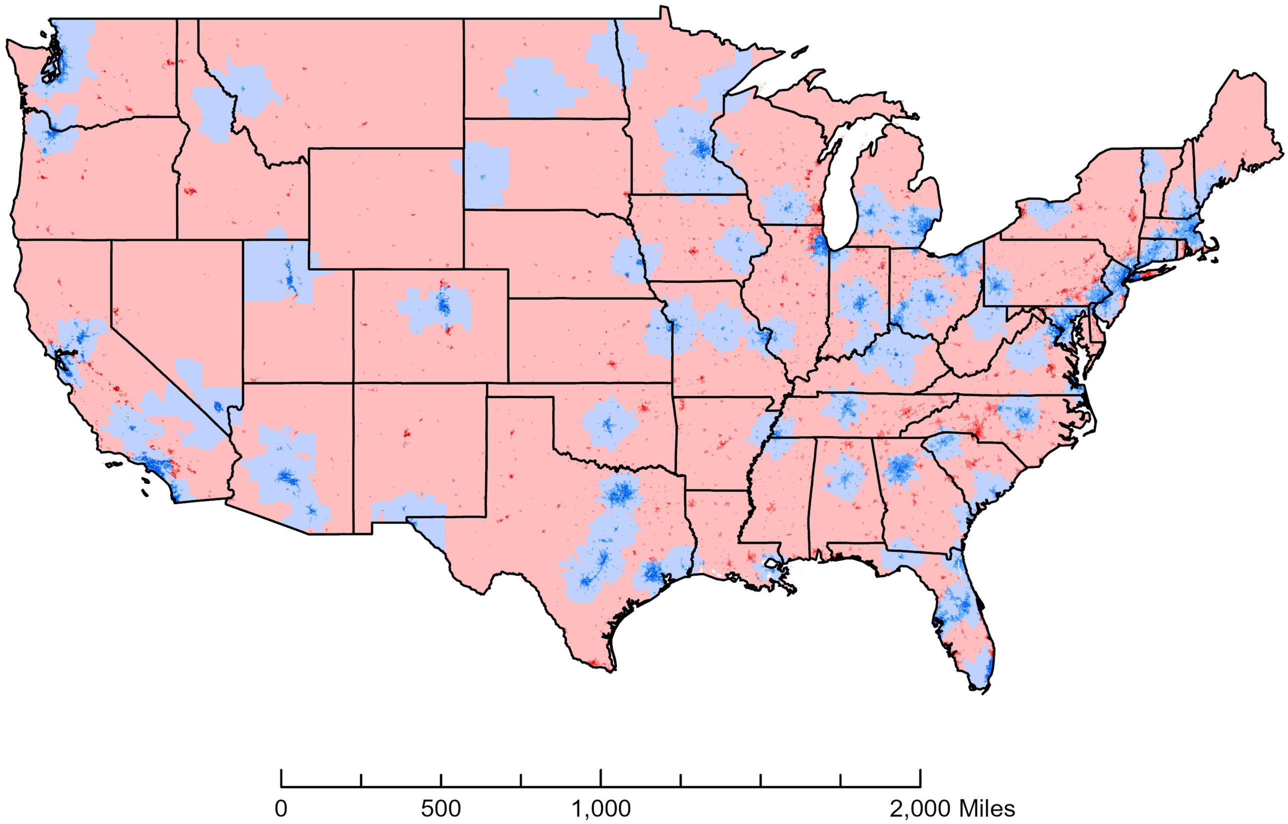

Figure 4 Drive time radii overlayed on population density quartile map. All regions outside of an accessible distance of an ocular oncologist are shaded red and all regions within an accessible distance of an ocular oncologist are shaded blue. Darker shades of red indicate areas with a higher population density quartile. Darker shades of blue indicate areas with a higher population density quartile.

Legend
- More Than 60 Minutes And Quartile 1 (Lowest Density)
- More Than 60 Minutes And Quartile 2
- More Than 60 Minutes And Quartile 3
- More Than 60 Minutes And Quartile 4 (Highest Density)
- Within 60 Minutes And Quartile 1 (Lowest Density)
- Within 60 Minutes And Quartile 2
- Within 60 Minutes And Quartile 3
- Within 60 Minutes And Quartile 4 (Highest Density)

tract analysis, our study yielded that approximately 45.9% of the rural population is living outside of an accessible distance of an ocular oncologist.[20] While Lieu et al's analysis is limited by the fact that it was done based on the number of ocular oncologists in each state, the present study provides a more precise analysis by only including census tracts

Table 3 Social Determinants of Health (SDOH) Analysis Separated Population and Household

	Within Accessible Distance	Proportion of Total within Accessible Distance	Outside Accessible Distance	Proportion of Total outside Accessible Distance	p-Value[1]	Effect Size
SDOHs by Population						
Education						
High school graduate (Individuals > 25 years old)	134,026,246	88.5%	66,110,351	87.9%	**<0.0001**	−0.015
Bachelor's degree (Individuals > 25 years old)	56,339,930	37.2%	19,981,014	26.6%	**<0.0001**	0.021
Low English proficiency (Individuals > 5 years old)	10,299,990	5.0%	5,956,471	2.9%	**<0.0001**	0.116

(*Continued*)

Table 3 (Continued).

	Within Accessible Distance	Proportion of Total within Accessible Distance	Outside Accessible Distance	Proportion of Total outside Accessible Distance	*p*-Value[1]	Effect Size
Insurance						
Insured	198,529,350	91.7%	98,862,716	91.2%	**<0.0001**	0.035
SDOHs by Household						
Economic Characteristics						
Median Household Income	$90,533		$69,916		**<0.0001**	0.553
Poverty (Families with children)	4,400,096	8.1%	2,741,420	9.9%	**<0.0001**	−0.063
Internet Access						
Broadband Internet Access	76,340,644	34.8%	37,323,224	33.8%	**<0.0001**	0.125
Vehicle Access					**<0.0001**	0.060
No vehicles	7,841,993	9.4%	2,693,830	6.3%		
One vehicle	28,023,286	33.4%	13,623,448	31.9%		
Two or more vehicles	47,968,732	57.2%	26,555,074	62.1%		

Notes: [1]Chi-squared test; two-sample t-tests; bolded p-values indicate statistical significance ($p < 0.05$).

Table 4 Overall Characteristics of University of Illinois (UI) Hospital Patients

	Overall, N=165	Outside Accessible Distance[1], N=79	Within Accessible Dsitance[1], N=86	*p*-Value[2]
Age (years)				0.246
Median (Q1, Q3)	64 (52, 72)	66 (52, 75)	63 (52, 71)	
Sex				0.811
Male	85 (50.9%)	42 (51.9%)	43 (50.0%)	
Female	82 (49.1%)	39 (48.1%)	43 (50.0%)	
Basal Diameter (mm)				0.616
Median (Q1, Q3)	11.5 (8.9, 14.1)	11.2 (8.9, 13.5)	11.7 (9.0, 14.4)	
Tumor Thickness (mm)				0.621
Median (Q1, Q3)	5.3 (3.3, 8.4)	5.1 (3.4, 8.6)	5.4 (3.3, 8.2)	
Volume (mm3)				0.604
Median (Q1, Q3)	291 (134, 659)	312 (102, 599)	278 (159, 746)	
Treatment				0.365
Brachytherapy/Proton beam	142 (86.1%)	70 (88.6%)	72 (83.7%)	
Enucleation	23 (13.9%)	9 (11.4%)	14 (16.3%)	
Extraocular Extension	4 (2.4%)	0 (0.0%)	4 (4.7%)	0.122
Metastasis	22 (14.7%)	12 (17.6%)	10 (12.2%)	0.347

Notes: [1]n (%). [2]Wilcoxon rank sum test; Chi-squared test; Fisher's exact test.

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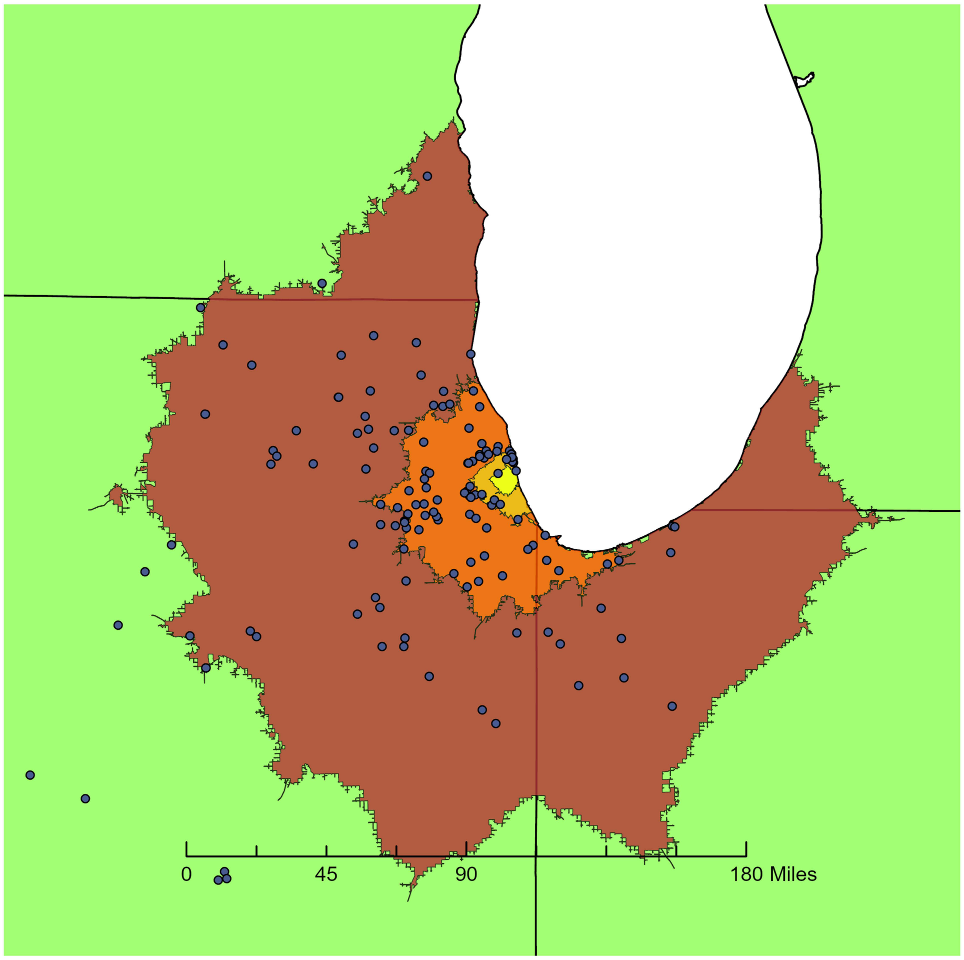

Figure 5 Map of the Chicagoland area with 15- (yellow), 30- (light Orange), 45- (dark orange), and 60-minute (red) drive time radii around University of Illinois Health (UIH). Black dots represent approximate locations of UIH patients.

Legend

Drive Times (minutes)

0 - 15

15 - 30

30 - 60

60 - 120

UIH Patients

within 60 minutes of an ocular oncologist's office address (as seen in Figure 4).[20] Thus, our results and figures suggest that the relative demand for ocular oncology care is most likely higher than originally proposed by Lieu et al.[20] Living in regions that do not have adequate access to ocular oncologists may lead to significant delays in care. Delays in or lack of

Table 5 Multivariate Linear Regression Analysis for Tumor Thickness, q-Value Represents p-value After False Discovery Rate Correction for Multiple Testing

	N	Beta	95% CI	*p*-Value[1]	*q*-Value[2]
Naturalized US Citizen	165	−0.166	(−0.259, −0.073)	<0.001	0.068
Respiratory Hazard Environmental Justice Index	165	−0.143	(−0.239, −0.048)	0.003	0.09
Prostate Cancer Diagnosis Rates	132	0.154	(0.050, 0.257)	0.004	0.09

(*Continued*)

Table 5 (Continued).

	N	Beta	95% CI	*p*-Value[1]	*q*-Value[2]
High Blood Pressure	165	0.139	(0.045, 0.233)	0.004	0.09
Lifetime Inhalation Cancer Risk	165	−0.135	(−0.229, −0.041)	0.005	0.09
Households Below Alice Threshold	163	0.132	(0.038, 0.227)	0.006	0.093
Specialist Physicians Per Capita	165	−0.12	(−0.215, −0.026)	0.013	>0.999
Rent Burdened	165	0.083	(−0.012, 0.178)	0.088	>0.999
Optometrists Per Capita	75	0.066	(−0.065, 0.197)	0.319	>0.999
Primary Care Physicians Per Capita	165	−0.104	(−0.199, −0.009)	0.032	>0.999
Individuals Living in a Food Desert	165	0.038	(−0.058, 0.134)	0.434	>0.999
Water Polluting Sites Environmental Justice Index	165	−0.644	(−1.248, −0.041)	0.037	>0.999
Chemical Accidents Environmental Justice Index	165	−0.032	(−0.129, 0.066)	0.523	>0.999
Particulate Matter Environmental Justice Index	165	−0.082	(−0.178, 0.014)	0.095	>0.999

Notes: [1]Multivariate linear regression controlling for age and gender. [2]False discovery rate (FDR) correction to adjust for 118 multiple testing; $q < 0.05$ is considered to be statistically significant.

Table 6 Bivariate Analysis of Referral Patterns and Symptom Duration Before Seeing Ocular Oncologist

	Outside Accessible Distance (n = 81)	Within Accessible Distance (n = 86)	p-value[1]
Mean Number of Referrals (SD)	1.75 (1.39)	1.39 (0.797)	**0.046**
Mean Symptom Duration Before Seeing Ocular Oncologist (SD)	9.58 (12.88)	7.19 (7.18)	0.145

Notes: [1]Bolded p-values indicate statistical significance ($p < 0.05$).

uveal melanoma care may result in complications such as vision loss, extraocular extension, and metastasis.[27,28] Our findings may have important future policy implications for addressing this disparity in access. For example, tele-ophthalmology, which allows for virtual visits, may aid patients in rural and/or underserved communities to be seen quicker. The use of tele-ophthalmology may be warranted for quick referrals for higher levels of care or even for clinicians, such as primary care providers or optometrists, to consult ocular oncologists when seeing a patient with a lesion suspicious for UM.

Geographic location not only determines one's ability to access healthcare based on proximity, but it can be associated with a variety of other SDOH. Our national service analysis demonstrated that individuals from areas outside an accessible distance of an ocular oncologist were significantly more likely to be impoverished, have a lower median household income, or be uninsured than those within an accessible distance. Patients that experience financial barriers to care have previously been described to have a lower survival rate, more advanced disease, and reduced likelihood of receiving surgical intervention.[29,30] Furthermore, in Rajeshuni et al's study, uveal melanoma patients who are socio-economically disadvantaged have previously been found to have a lower all cause survival, which may suggest comorbidities and other non-cancer related factors contribute to overall mortality.[29] These findings are similarly reflected in Mensah et al's, in which they found significant decreases in survival with higher social vulnerability score.[30] Given the established link between financial barriers to care and increased morbidity from uveal melanoma, our findings from the national service analysis underscore important SDOH that may further limit access to ocular oncology care in addition to geographic barriers. In addition to financial barriers, individuals from regions outside an accessible distance of an ocular

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oncologist were also significantly less likely to have a high school diploma, a bachelor's degree, and broadband internet access, which may lead to a decreased functional health literacy and further complicate access to care.[31]

The national geographic service analysis noted above has several limitations. Firstly, determining whether regions were within or outside of an accessible distance of an ocular oncologist was based on driving time, which assumes access to a vehicle and potentially ignores other forms of transportation, such as a train. Furthermore, although several ophthalmological societies were used to generate a comprehensive list, it is likely that some ocular oncologists who provide UM care may have been omitted from our list. Additionally, patient-level outcome data for the national analysis were unavailable, which limited our ability to assess how the aforementioned geographic or SDOH factors impact UM care on a national basis.

The retrospective portion of this study sought to determine the role of SDOHs, environmental factors, and geographic factors on the presentation and management of UM patients at UI Hospital. As seen in our study, patients who lived outside an accessible distance of UI Hospital did not appear to have any significant differences in presentation of UM. Additionally, we also hypothesize that the lack of differences based on geographic proximity may also be attributed to the fact that the analysis is essentially comparing individuals that live in a suburban area to those living within an urban area. We also hypothesize that the lack of differences between patients outside and inside of an accessible distance may be due to these patients having alternative transportation modes of reaching UI Hospital (such as local rail lines). Patients who live within the city who take the subway or a bus, as opposed to driving, may have longer travel distances/times which may also explain the lack of differences. As a result, other SDOHs, such as education or income, might be more homogenous amongst our patient sample, regardless of geographic proximity. Although the presentation of UM appears to be unaffected by geography, geography may have played a role in its management. Patients living outside of an accessible distance of UI Hospital had a significantly higher mean number of referrals prior to seeing an ocular oncologist at UI Hospital than patients living within an accessible distance. Having a higher referral burden may lead to further delays in care by increasing logistical and financial burden on patients, including more appointments, travel, time off work, and potential out-of-pocket costs.[32–34]

Although no significant relationships were identified between the presentation of UM and SDOHs/environmental variables in this patient sample, several notable trends were identified. For instance, there was a trend for patients from areas with fewer naturalized US citizens and from areas with more households below the ALICE threshold to have larger tumor thicknesses. As these are indirect measures of socioeconomic status, this trend may be explained by the previous literature detailing socioeconomic status having a negative impact on UM prognosis.[6,29,30] Moreover, several studies have previously identified a relationship between several SDOHs and the presentation of UM at diagnosis. For example, Choudhry et al found in their study that higher-income individuals were significantly less likely to have an advanced tumor stage at diagnosis.[6] Furthermore, they also discovered that patients with no insurance or with Medicaid were significantly more likely to have an advanced tumor stage at diagnosis.[6] These findings are similarly reflected by studies conducted by Shildkrot et al and Rajeshuni et al, indicating that a higher socioeconomic burden is related to a worse UM presentation at diagnosis.[29,35] Additionally, these SDOHs are not only associated with the presentation of UM at diagnosis, but also the treatment a patient may receive. For instance, socioeconomically disadvantaged patients were significantly more likely to have enucleation as treatment for UM.[29] Environmental variables chosen for analysis in this study, such as pollution indices and inhalation cancer indices, were not found to have a significant relationship to the presentation of UM in this patient cohort. We hypothesize that environmental variables were not found to have a significant relationship to the presentation of UM in this cohort because of low spatial variation between patients. In other words, patients within a 60-minute travel time of UI Hospital live within the city and they were compared to patients who lived outside a 60-minute travel time radius, some of whom also live in the city limits. Additionally, zip code was used to obtain environmental variables, which may lack granularity and result in homogeneity of environmental variables of patients in this cohort.

The retrospective portion of this study has several limitations. Firstly, SDOHs and environmental factors were assigned to each patient by using their zip code. The usage of zip code leads to an indirect measure of the SDOHs and environmental factors in which a patient may live, and thus, it may not be reflective of the true SDOH and environmental burden that each patient actually faces. Furthermore, since the entire patient cohort is from a single institution, the generalizability of this study is limited. As mentioned previously, the geographic analysis used in this study to determine if a specific patient lived outside of or within an accessible distance of UI Hospital was based on driving times, which ignores other potential modes of transportation and assumes that the patient has access to a vehicle. Given the above limitations, it may be warranted to use a more granular form of measuring SDOHs and environmental factors for a given patient, such as using census tracts rather than zip codes. Furthermore, future research is warranted to validate our findings using a multicenter design to help increase the generalizability and spatial variation between patients with UM.

Conclusion

Based on our national service analysis, geographic and SDOH disparities exist in accessing ocular oncologists who manage UM. This study highlights key areas where access to ocular oncologists is limited, such as the rural regions of the US. Since early intervention in UM is crucial for improving patient mortality and morbidity, addressing the disparities in accessing ocular oncologists nationwide is important for ensuring more equitable access. Furthermore, the retrospective analysis of our study on UM patients seen at UI Hospital yielded that geographic proximity may play a significant role in referral burden, which may act as another barrier to providing high-quality care. Moreover, trends between being from an area with a lower socioeconomic status and a higher tumor thickness indicate the need to further evaluate this relationship with a larger sample size and a multicenter design.

Data Sharing Statement

Data for the national analysis can be accessed via the US Public Census data. Patient-specific data of patients from UI hospital is not available for sharing as explicit consent was not received from patients.

Ethics Approval and Informed Consent

For patient-specific data collected from UI Hospital, the Institutional Review Board approval (STUDY2023-0866) for this study was obtained from the University of Illinois Chicago. The Privacy Notice informs patients that their records may be used without their authorization if approved by the IRB, and because study procedures are in place to protect confidentially information learned during the study will not affect the treatment of the participants and thus will not adversely affect their welfare. This study is in compliance with the Declaration of Helsinki.

Consent for Publication

No images, videos, or recordings of individuals are included in this manuscript and thus consent is not needed. All figures in this paper were produced by the authors.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare no potential conflicts of interest.

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